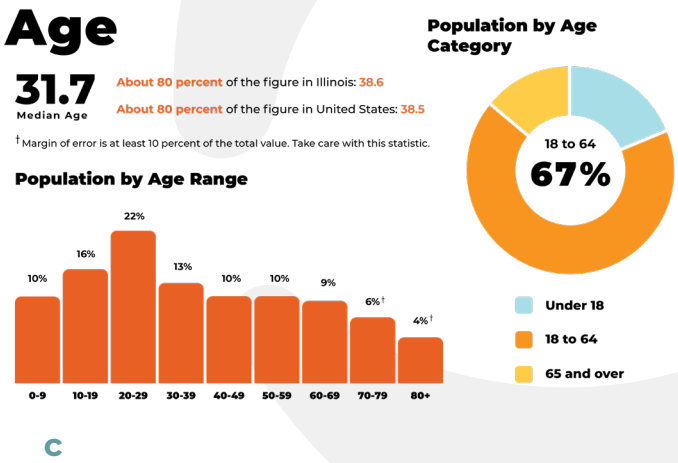
Overview: Design Goals & Project Context

The goal of ADAPTHAUS is not only to design and construct a “Net-Zero” home at a price that is economically feasible in Champaign, IL, but to create a design that can be used nationally for its environmental sustainability and construction simplicity. ADAPTHAUS, staying true to its name, solves this problem through dynamic and flexible solutions for its clientele. The team’s design optimizes the home’s performance, fits in with the surrounding neighborhood, remains energy efficient, and is still affordable.



Our team believes that eliminating the need to move as an individual’s spatial needs change throughout their life will significantly reduce the environmental effects and financial burdens to construct an entirely new house. As per ACS 2019 census data, Champaign Urbana has a population of 226,033 with a median age of 31.7 years. The dominant age range group was 20-29, consisting of 22% of the total population. We decided to focus our design keeping requirements of young professionals in their mid-to-late 20’s as our primary focus, who recently graduated from college and have some working experience to serve the majority of the local community requirements. The design intent is that young professionals will only purchase and install the house’s main module, serving as their beginning point where their basic needs for a home can be met. As the young professional grows older and as their spatial demand and financial capacity increases and possibly starts a family, they can attach more modules to the main module.

The house has been designed with the provision of future expansion in mind that allows extension of existing architectural and MEP services. When the child grows up and moves out of the house, the parents can sell or rent out (or through listing on Airbnb) the other two modules to generate revenue from their unused space. This allows for the maintenance of a single home throughout one’s life. The house is designed to accommodate the ever-changing natures of living, playing, and working spaces. An increased need for virtual communication, divisible workspaces, and convertible functions was prominently considered while planning the house. Simultaneously, opportunities are provided for the spaces to be used for variable functions during different times of the day, optimizing the energy and operating costs. By adopting prefabricated construction methodology, the whole construction process would benefit from significantly lower building costs, shorter construction timelines, less possible re-

work, and better quality which would revolutionize the single-family housing industry. The house would set an example of high-performance, energy-efficient housing in the community.

Unique Design Features (that enhance house value)

ADAPTHAUS adapts unique features in the design phase, aiming to use clean solar energy, reuse the available water sources, and applying integrated smart home devices to reduce future operation and maintenance costs. The Illinois Solar Decathlon design team also focused on providing an energy-efficient lifestyle, including off-grid capabilities for a family-sized home. Although many commercial buildings nowadays utilize solar panels to generate energy, such uses on small residential housings are still minimal. Our team tries to use our design to prove that solar panels are affordable for regular housing while making them future-proof. 24 Solar panels have been installed on the rooftop to provide enough electricity for a household to be used at all times. The unused/excess electricity will be stored in a BigBattery, which can be used anytime or traded for utility credits through net-metering, thus providing energy all year round.

The Illinois Solar Decathlon Team proposed integrating a landscape-direct greywater system into this house in our initial plan. If this system is approved, it will be the first housing or building to reuse greywater and apply the recycled water concept in Illinois. This system would collect water from the washing machine and shower, channel it through a simple settling tank, and reuse the water for irrigation purposes. However, the greywater system hasn't been approved yet as we were writing this report. We leave the greywater pipe connections in place without the fully built system, so the future owner of the house has the option to add such a system by connecting the pipes, which would result in an estimated annual water savings of $33. The HVAC system designed with smart material choice allows them to adapt to the extreme winter nights and scorching summers. The mechanism includes a system to maintain the external surface temperature and internal air humidity within the optimal comfort zone as defined by ASHRAE (The American Society of Heating, Refrigerating and Air-conditioning Engineers) standards. To prevent heat loss/leaks, this design includes layers of rigid and spray foamed insulations to minimize the leaks and maintain a net-zero energy housing.

In addition to these new technological features, some changes are reinvented ideas from the past. A couple of examples include the use of PEX piping and a tankless electric water heater. By using PEX piping, future maintenance costs are reduced significantly as it is much easier to maintain, much more flexible, and cheaper on an upfront-cost basis. Its flexibility means resistance to cracking and freezing, which can work as an additional safety precaution during the midwest's harsh winters. As mentioned before, electric tankless water heaters work to reduce in many areas. Aside from cutting down on space used, they reduce the amount of water being stored, reducing the amount of energy needed to

constantly keep that water heated as water is simply heated as it is required. This also eliminates natural gas use as it is entirely electric and optimizes energy consumption through its self-modulating flow for when water is needed throughout the home.

The above unique design features enhance the home's market value and fit perfectly with our target clients because young professionals would care about energy usage and embracing the convenience the technology brings to them. For the same reason, the house's initial cost is high, almost doubled compared to the neighboring house. However, in the long run, these high-tech features would only bring further benefit to the homeowner.

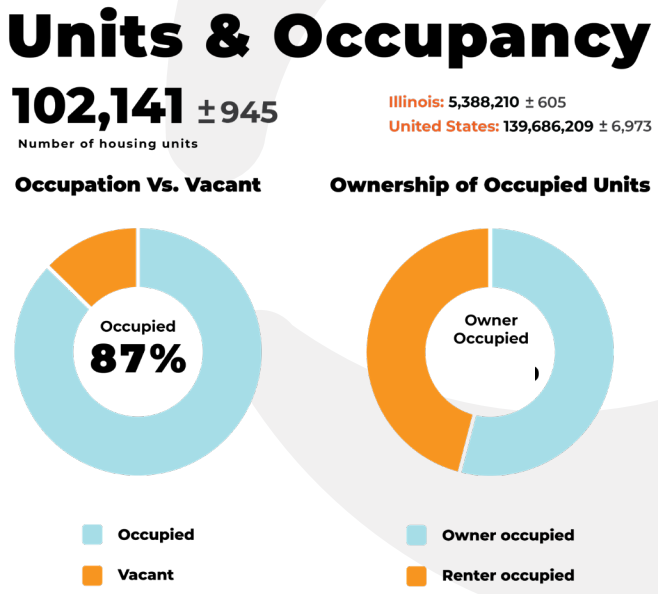


Figure 2.

Market Needs and Expectations

As seen from above, around 46% of occupied units are rented, which suggested the need for more affordable housing. As seen below, the median value of the house is $158,700 (Our single module falls around the 200-300k category)

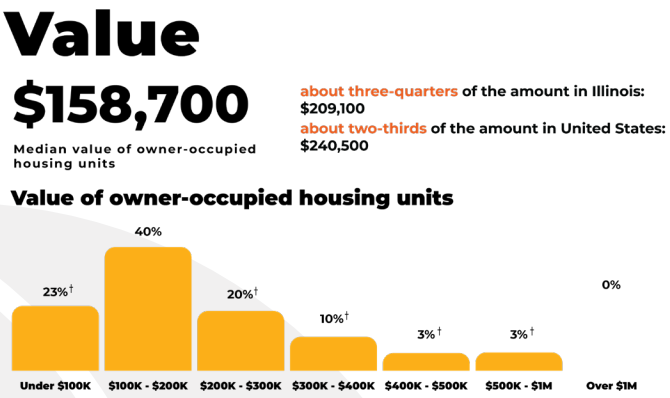


Figure 3. Value of owner-occupied housing units

Low-income renters seeking affordable housing in Champaign County have waited as long as two years for help.

Indeed, there are 5,210 individuals on the waitlist for all properties and programs that the Housing Authority of Champaign County supports, according to the authority's 2020 Fact Sheet.

Construction Cost Breakdown

Table 1: Estimated Construction Cost Breakdown by Module

	Main Module	Module 2	Module 3 (future upgrade)
Structure	$49,250	$49,250	$49,250
MEP & Equipment	$75,150	$4,000	$4,000
Finishes	$23,357	$23,575	$23,575
PV Panel	$25,426	$4,000	$4,000
Furnishings	$10,000	$7,000	$7,000
Landscaping	$20,000	$2,500	$2,500
Total	**$205,401**	**$90,325**	**$90,325**

Feasibility Study On The Main Module

A financial analysis was performed to demonstrate the affordability of this home, particularly on the main module, which is the most expensive investment since the equipment that services all three modules must be initially purchased with the Main Module. However, the cost for the following modules would be much less because most MEPs are completed in the main module. The target market - a young couple, both in their mid-20's with a few years of work experience, will start by purchasing the Main Module. According to Payscale, the average salaries for the University of Illinois at Urbana-Champaign graduates in 2019 are around $77,989, with an early career salary of $66,000. However, given the economic downturn and applying the median household income for Champaign, IL, we have estimated that their combined income is $100,000, a very conservative estimate for university graduates with some working experience. After all taxes, the tenants would take home $5,021.95 a month after tax. The house is affordable for our target clients because no more than 28% of their after-tax income should go to a mortgage or rent payment.

Table 2: MHI Calculation for a young professional couple

Income	
Monthly Gross Income	$ 8333.33
Federal Tax Rate	0.0734
State Tax Rate	0.0467
FICA Tax	0.0765
Total Effective Tax Rate	0.1966
After Tax MHI	$ 6695
28% After-Tax MHI	**$1874.6**

The cost of the first module is approximately $205,401, with the mortgage being about $143,781 for a Loan-to-Value of 70%. The interest rate on the standard 30-year mortgage would be 3.75%, assuming a 30% down payment, resulting in monthly payments of $976. To save up the required down payment of about $61,620 in 6 years, the couple would only need to save $1,000 a month to achieve this. The Main Module's assessment value is 33.3% of the fair market value, giving a yearly property tax of approximately $6,500. Monthly

household debt includes property tax, insurance, utility, and mortgage costs as well as car lease payments, the minimum owed on a credit card balance, and student loan payments, if applicable. Utility costs are incurred because internet access and water are required.

Table 3: Loan Calculation On The Main Module

Loan	
Interest Rate	3.75%
Period	30 Years
Total Cost	$ 205,401
Loan Amount	$ 143,781
Payment	$ 450

According to Value Penguin, the average yearly home insurance cost in Champaign, IL, is $1,206, an insurance agency.

Although initial capital costs are typically higher for a net-zero energy home, many government-provided incentives help mitigate the costs of generating renewable energy. For example, the Federal Investment Tax Credit can help reduce up to 26% of the costs of implementing a solar power generating system. Any excess energy that the home produces will be sold back to the grid via the local utility's net-metering program. The homeowners will also sell their Illinois Solar Renewable Energy Credits (SRECs) for the first 15 years, making almost $10,000. The reduction in principal from receiving the Federal Investment Tax Credit is assumed to occur at the beginning of year two. The owner will pay the thirteenth payment with the tax incentives. As a result, there will be a reduction in the monthly loan.

Home Extension: The Second & Third Modules

As the design concept suggested, the target market will only need to purchase and add more modules as their spatial needs increase throughout their lifetime. The option would make sense later in life when their salaries have increased, and the couple has been able to save up to approximately $95,000 for each module. With these additions, the family would also be adding more solar panels so the cost of electricity would balance to zero. Later, if the family rents out the extra space, they could bring approximately $400 per month in revenue based on apartments for rent nearby in Champaign, IL. This could provide them with additional cash flow and security into retirement.

From a financial standpoint, purchasing this home is feasible for most young professionals and an excellent investment that will save them money over the long run and even generate income for them.

Cost Estimate and Actual Cost

Contract Value	$350,000.00
Contingency (included in contract value)	-$30,000.00
Change Order	$21,498.62

Landscape contract Value	$18,795.00
Sponsorship cost total	$161,401.98
Total Project Cost	$521,695.60
Total Project Cost (with no change order)	$500,196.98

The project was eventually constructed in two modules, leaving the third module's decision to the future homeowner and making this house more affordable at the first stage. If these two modules were manufactured in the factory and complete the connection on-site, the project cost would be around $300,000 based on our original contract with Skender. DuriUnfortunately, during the project planning phase, COVID-19 became a significant issue that put all construction firms into great trouble. Our initial design of having all two modules first manufactured in Skender's factory and then complete on-site didn't carry out as planned because our initial partner, Skender, permanently closed their manufacturing factory. Because the steel framing modular unit manufacturing business is still under market testing, very few companies have experience working with steel-framed modular housing, and we can't find another potential partner in the midwest area under this short timeframe. The final design has been changed to wood framing, and the construction method is changed to stick-built while keeping the exterior shape unchanged. Although switching from steel framing to wood framing should bring down the construction cost, the rising labor and material costs due to the global pandemic eventually turned this project to be a $500,197 project, higher than our estimate of $393,951 for two modules by 27%. This project is about twice the price of neighboring houses because it includes features originally applied to commercial buildings, such as PV systems, CERV units, etc. These unique features incorporated in our design drive up the final project cost. However, as long as more and more people care about clean energy and use such applications in their residential housing, the price for these systems will come down eventually, and everyone should be able to afford them. We would like to set an example to the community and be the pioneer in leading better and cleaner housing options.

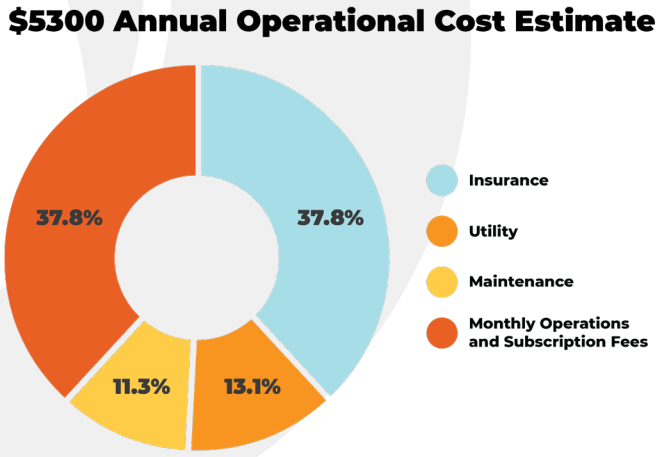


Figure 4

Operational Cost Estimate

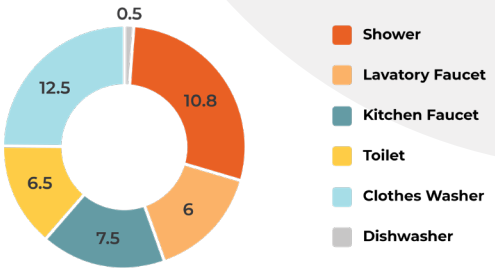
Our team has also established an operational cost estimate for the project upon its completion. Every year, ADAPTHAUS should cost its residents an average of **$5300,** including utilities, insurance, maintenance, and any monthly operations and subscription fees relevant

to the climate and location, as shown in the figure above.

The utility cost of $692 consists of electricity, water, and sewage. Based on evaluations using BEopt (Building Energy Optimization Tool) software, ADAPTHAUS should use approximately 7500 kWh/yr; the project's photovoltaic system should produce over 9500 kWh/yr. ADAPTHAUS, therefore, produces more than enough electricity to power itself, reducing the annual cost of electricity to zero. For more detailed electricity information, see below.

The water and sewage portions of the utility fee were based on 2021 rates established by the Urbana & Champaign Sanitary District. Based on the average flow rate and average daily usage for each appliance, the everyday water consumption for ADAPTHAUS was determined to be about 55.4 gallons per day or 20,220 gallons per year. This amounts to a water bill of $601.91 per year and a wastewater bill of $90.18 per year, including a $5.24 stormwater utility fee based on the impervious surface area of the site. See tables relating to this calculation below.

ADAPTHAUS Indoor Water Consumption (in gallons, per person per day)



Total: 43.7 Gallons

Water Bill Items	Rate
Meter Facility Charge - ¾"	$32.48 / month
Residential Water Use Charge	$0.5851 / 100 gallons
Public Fire Protection Service Charge	$6.44 / month
Champaign Municipal Tax Addition	2.83%

Rates as of January 1, 2021

Rate Type	Rate Amount
UCSD Rate	$0.2714*
Sewer Use / Benefit charge	
- City of Champaign	$0.1289*
Bill Charge	$2.00
EFT only Bill Charge	$1.00
Email only Bill Charge	$1.00
EFT & Email Bill Charge	$0

*Charges are based on per 100 gallons.

ADAPTHAUS Indoor Water Consumption (per person per day)

Fixture/Appliance	Actual flush or flow rate	Units	Estimated fixture usage	Units	Estimated water usage (gal)
Shower	1.75	gpm	6.15	min	10.8
Lavatory faucet	1.2	gpm	5	min	6.0
Kitchen faucet	1.5	gpm	5	min	7.5
Toilet	1.28	gpf	5.05	flushes	6.5
Clothes washer	N/A				12.5
Dishwasher	4.7	gpc	0.1	cycles	0.5
Note: clothes washer water consumption is based on ENERGY STAR database				Total	**43.7**

Single Family Residential Customer Monthly Billing Amount		
Tier	Impervious Area	Monthly Fee
1	500 to 6,000	$5.24
2	6,001 to 8,000	$11.18
3	Over 8,000	$14.46

Non-Residential Property (Rate/ERU*) Monthly Billing Amount	
*ERU = Equivalent Residential Unit = 3,478 sq	
Rate per ERU	$5.55

The insurance for the approximately 1200 square foot home was determined to be approximately $2000 per year through consultation with a local homeowners insurance group, Prairieland Insurance Group LLC. The rate is largely based on the

home's value and location and reflects what it would cost to rebuild the home without sponsorship or volunteer work.

The maintenance costs for ADAPTHAUS should be meager, considering how recently it was constructed and how efficiently space was designed. For most Americans, a large portion of maintenance comes from lawn care and general landscaping, which ADAPTHAUS effectively avoids by using local and sustainable vegetation. A common practice is to budget $1 per square foot of a home for annual repairs and maintenance; given ADAPTHAUS's site efficiency and recent construction, we can confidently devote $0.50 per square foot or $600 annually.

Finally, the monthly operations and subscription fees are services that residents of the home could reasonably be expected to pay for. A basic household internet package costs an average of about $50 per month, and according to J.D. Power, the average American cell phone bill is $70 per month, and the average American household pays $47 per month on cable or streaming services. Based on these rates, the annual cost of operations and subscriptions can reasonably be estimated to be approximately $2000.

Payback Period for PV System

The Illinois Solar Decathlon team has a firm belief in clean and renewable energy, so is the city of Champaign. The SOLAR URBANA-CHAMPAIGN program will single-handedly avoid greenhouse gas emissions equivalent to 4,190,413 lbs. of CO2 each year with PV systems installed. This program can save residents between 15% and 20% on the installation of solar panels. Since 2016 when the city initiated the program, 242 properties have added solar, and 2,094 kilowatts of solar capacity have been installed. Therefore, we support the city's solar panel initiative by installing 24 solar panels on our project.

Since ADAPTHAUS is utilizing BigBattery's repurposed Electric Vehicle batteries, the battery cost is significantly reduced, reducing the net cost of the PV system. ADAPTHAUS's system costs approximately $24,000.00. To model the cost analysis of ADAPTHAUS, two other systems will be looked at SolarEdge Energy Hub and Generac 7.6 kW PWRcell system. The Generac PWRcell is a simple yet popular solution to battery storage for homeowners that costs more than $4,000.00 more than ADATPHAUS' system. Looking at more of a cost effective design, the original PV design of ADAPTHAUS consisted of SolarEdge's Energy Hub solution: SE7600 inverter, backup interface, optimizers, energy meter, and the LG Chem RESU10H battery. The overall retail cost for a system of this caliber is roughly $2,000.00 more than ADAPTHAUS with the most significant cost coming from the battery.

The biggest cost of ADAPTHAUS PV system stems from the installation which makes up for almost one third of the costs. The cost per watt of the system is $3.10. Although the price is high, PV systems can be made affordable with incentives. There is a Federal Investment Tax Credit (ITC)

for 26% for new PV systems. Along with the ITC, Illinois also has Solar Renewable Energy Credits (SRECs). One Illinois SREC is equal to one megawatt hour of electricity generated by a solar system. One SREC is roughly $70 in the state of Illinois which can be produced for 15 years. SRECs are paid upfront, so it is a grand incentive for prospective solar homeowners. Based on a system degradation of 0.5% each year, ADAPTHAUS is anticipated to have a total SREC incentive of over $10,000.00 over the course of 15 years, roughly $600.00 each year. Based on the incentives, the payback period for ADAPTHAUS is 6 years. During this payback period, ADAPTHAUS will be net positive so homeowners will not have to pay for any additional electricity from the grid. Since the PV system has a lifetime of at least 25 years, the system will be saving the homeowners a lot of money for an additional 19 years after the payback period. With an addition of a PV system, there is a 3-4% increase in home value.

The NPV over the course of 25 years is $12,708.90 indicating the PV investment is worth it as ADAPTHAUS is net positive while also providing federal and state tax incentives. With operation and maintenance costs at approximately $130 each year, the SRECs could easily settle these costs while also providing a cushion for minor unexpected costs in the system

Costs (Taxes Included)	MRP
SE3800H Inverter	$1,130.00
(12) P370 Optimizers	$840.00
(24) Mission Solar Panels	$4,608.00
UNIRAC Racking System	$2,216.48
Outback Skybox Hybrid Inverter	$2,860.00
(2) BigBattery Husky Batteries	$4,398.00
PV Installation Costs	$7,350.00
Ballast Blocks (68)	$65.00
Fire Raptors	$350.00
TOTAL	$23,817.48

Additional Space to Generate Revenue

One of the unique opportunities that have presented itself during recent years, would be gig renting, or sites like Airbnb, which allow you to rent for shorter periods of time even as short as a day. Given this opportunity in the current housing market and the location, an average monthly revenue to be expected in the Champaign area would be averaged at about ~$1300 for a 2 person house/apartment. Considering this modern design, how recent, and clean this home is, it would very comfortably be listed at $1500-$1800 for an entire month. The market is always shifting and changing and therefore this opportunity would be something to capitalize immediately after the home finished construction, in the event it did not have immediate renters. Other gig renting sites that the home would be able to be posted on would include VRBO and booking.com, adding variability to a unique opportunity.